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Material Testing Program for NOVA PVC and Epoxy

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1. Introduction

The Totally Active Scintillator Design (TASD) relies on the use of PVC extrusions as the main structural support. This presents a problem because PVC extrusions are typically not used as structural members and there are no commonly used design references or design specifications that can be used as a guide when designing the TASD structure. As a result it is necessary to perform an R&D program on the PVC, the extrusion structures, and epoxy being used in order to have a thorough understanding of their properties to form the basis for designing the structure. The purpose of such an R&D program is threefold:

- To investigate the properties of PVC and the effect of titanium dioxide on the strength and creep properties of the material.
- To investigate methods for bonding PVC. There are two critical bonding applications. The first is the method of bonding the bottom seal and the fiber manifold to the extrusion. The second is the method for bonding extrusions together to form the TASD structure.
- To investigate the effect of liquid scintillator on the mechanical properties of the pvc and epoxy.

No one material property will give us insight into the performance of the PVC or epoxy throughout the lifetime of the experiment. However, by performing a wide range of tests on the mechanical properties of the PVC we can gain valuable insight and understanding of PVC/epoxy performance by examining all of this data together.

2. PVC Mechanical Properties.

The PVC pipe industry can be used as a guide as NOVA works to determine the PVC mixture that optimizes reflectivity, strength, and creep. PVC pipe has critical mechanical properties specified and not the composition of the PVC. The NOVA experiment needs to specify critical values of mechanical properties that any pvc mixture would need to meet. Creep is an especially difficult property to specify. For PVC pipe, the creep property is not specified in terms of strain rate or strain over a given time. Rather, it is specified as pipe failure under a rated load after 11 years. NOVA can set a similar specification as well as other properties as defined below.

PVC Test Samples

One of the main purposes of this test program is to vary the composition of the PVC in order to optimize the strength, stiffness, creep, and reflectivity of the PVC extrusions. To date, material testing of the pvc has been using samples cut from panel extrusions. PET and Extrutech have supplied extrusion panels with different compositions. However, a lower cost and more

straightforward method of systematically evaluating the affect of different compositions would be to work directly with a color house which is capable of providing extruded strips which then can be used in mechanical tests. A minimum of 10 samples should be tested in each of the mechanical tests described below.

Tensile Strength

Each sample should be subjected to standard ASTM tensile tests in order to determine the yield point and Youngs modulas of the material. These values can be used to compare the relative strength and stiffness of the different materials. The following ASTM standards should be used.

D6436-02 Standard Guide for Reporting Properties for Plastics and Thermoplastic Elastomers

D638-03 Standard Test Method for Tensile Properties of Plastics

In addition, tensile specimen should also be submerged in liquid scintillator and tested at intervals of 3, 6, 9, 12, 15 months in order to evaluate if liquid scintillator had an affect on the yield strength and stiffness (Youngs Modulas) of the material.

Creep

Creep is most likely the limiting mechanical property of PVC in the design of NOVA. For PVC pipe creep is the limiting factor in the design and creep strength is defined as the minimum stress at which a pipe will fail after 11 years. Two types of creep tests should be performed: standard creep tests; pressurizing extrusions similar to the pvc pipe standards.

The first set of tests would be a standard creep test using ASTM standards should be conducted in order to compare the relative creep properties of different materials. The purpose of this test is to determine the creep modulas which can then be used in an FEA analysis to investigate the deformation/stresses in the structure over time.

The following ASTM standards should be used as a guide for a test:

D2990-01 Standard Test Methods for Tensile, Compressive, and Flexural Creep and Creep-Rupture of Plastics

Using the above ASTM standards as a guideline, tensile specimen should be loaded at a number of representative stresses (250psi, 500 psi, 700psi, 1000psi, 1500psi) and the deformation under load measured over time. Identical tests should be conducted with specimens that are submerged over time in liquid scintillator.

A second set of creep tests would mimic the pvc pipe standards for defining strength. Three cell extrusions would be subjected to various levels of internal pressure (for example 20psi, 50psi, 75psi, 100psi) over time. The time to failure at each pressure would be measured. These tests would be repeated for specimen submerged in liquid scintillator. The purpose of these tests would be to give a relative indication of the strength of the pvc over time that is directly related to the geometry of the NOVA experiment.

Impact Testing
Either the Charpy V-notch test or the Izod impact test should be conducted to evaluate the impact toughness of the material. These tests would be conducted on different samples as a means of comparing the relative toughness of different compositions of pvc. Samples would be submerged in scintillator and at regular intervals (3, 6, 9, 12, 15 months) samples would be removed from the scintillator and tested in order to evaluate the affect of scintillator on the toughness of the material.

D4495-85 Test Method for Impact Resistance of PVC

Stress Corrosion Cracking
It is unknown if the liquid scintillator will initiate crazing and cracks in the pvc over time. It is possible that the scintillator could initiate cracks that would continue to grow until they reached a critical value in size that would lead to failure. The creep tests that are submerged in liquid scintillator would basically be testing for stress corrosion cracking. It is important that some of the samples used for the creep tests were at relatively low stress (i.e. 50-100psi). At these low stresses creep would not be a problem but if stress corrosion is occurring then we would see significant deformation as a result.

Stress Relaxation
Over time stress relaxation occurs in plastics. Testing should be performed to understand the extents to which the PVC will stress relax. The following ASTM standard can be used:

D2991-84 Practice for Testing Stress-Relaxation of Plastics

3. Epoxy Testing
There are two applications of epoxy in the TASD structure. The first use of epoxy is to attach the end plug and manifold. The second use is to bond adjacent planes of extrusions to each other. The requirements for each of these applications are not the same and different epoxies could be used.

In order to evaluate these epoxies standard shear and tensile test should be conducted according to the following ASTM standards:

D6465-99 Standard Guide for Selecting Aerospace and General Purpose Adhesives and Sealants

D4896-01 Standard Guide for Use of Adhesive Bonded Single Lap-Joint Specimen Test Results

D3164-03 Standard Test Method for Strength Properties of Adhesively Bonded Plastic Lap-Shear Sandwich Joints in Shear by Tension Loading

D3163-01 Standard Test Method of Determining Strength of Adhesively Bonded Rigid Plastic Lap-Shear Joints in Shear by Tension Loading

D1144-99 Standard Practice for Determining Strength Development of Adhesive Bonds

It is important to follow these standards in order to be able to compare the results with manufacturer's data which has been developed using them.

Several epoxies have been tested already with pvc extrusions. To date none of these epoxies have been tested using the standard testing methods described above. These tests should be performed in order to determine the relative strength of each epoxy in a systematic way. Also, for the epoxy chosen for the end manifold seals, test samples should be submerged in scintillator and then tested at different periods of time (3, 6, 9, 12, 15 months) in order to evaluate the affect of the liquid scintillator on the strength of the bond.

4. Conclusion

This paper has outlined a systematic test program for evaluating the material properties of pvc and epoxy. The purpose of this test program is to determine the relative strengths of different formulations of pvc and epoxies in order to chose the material that best meets the requirements for NOVA.